PATENT SPECIFICATION

851,379

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COMPLETE SPECIFICATION

DRAWINGS ATTACHED

Aircraft

We, POWER JETS (RESEARCH AND DEVELOPMENT) LIMITED, a British Company, of 25, Green Street, London, W.1., do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to aircraft, and particularly though not necessarily exclusively to aircraft operating on the "jet flap" principle. Examples of such aircraft are described in British Patent Specifications Nos. 787,011-5, 790,193-4, 790,298, 823,591-3 and 829,753, and the principles involved are discussed in a paper by the present inventor published in the Journal of the Aeronautical Society of January 1956.

It has been proposed that a jet flap aircraft should be powered by a number of wing-mounted jet engines arranged to discharge their jet streams so that they leave the wing trailing edge in the form of a long thin jet sheet. This usually necessitates leading relatively hot jet streams through the wing structures and the fire risk is thereby increased, especially when the fuel tanks are within the wing. The last-mentioned of the above Patent Specifications discloses an arrangement whereby the fire risk is reduced, and the present invention provides a modification of this earlier proposal.

The present invention is based on the use in a jet flap aircraft of jet engines of the type which in operation produce two propulsive jet streams at different temperatures, and particularly though not exclusively on the use of gas turbine jet propulsion engines of the by-pass and ducted fan types which in operation discharge a relatively cool stream of air—the by-pass stream—in parallel with the high temperature stream of exhaust gases from the turbine. Broadly it is contemplated that only the lower temperature stream shall be used to produce the jet flap effect.

Thus the invention provides an aircraft wing comprising stress-carrying structure including a front spar and a rear spar extending spanwise of the wing and a plurality of straight tubular members arranged side by side along the wing span and extending chordwise of the wing from a position forward of the front spar through the sparts to which they are rigidly attached to a position rearward of the rear spar, the tubular members being connected at their rearward ends to rearwardly directed jet nozzles, and further comprising at least one jet engine of the type which in operation produces two propulsive jet streams at different temperatures, the engine being connected to discharge the cooler stream through at least one of the tubular members and jet nozzles and the hotter stream through a separate rearwardly directed jet nozzle outside the wing structure and arranged so that the hotter stream is discharged clear of the wing.

In this way only the cooler stream has to be led through the wing structure in proximity to the fuel tanks and the fire risk is reduced.

The engines may be mounted in nacelles extending forwardly from the wing leading edge generally in the plane of the wing so that the cooler stream of each engine can be discharged directly into the tubular members while the hotter stream is led through a cranked duct to a nozzle below or above the wing surface and relatively close to the leading edge. In some cases the nacelles might be above or below the wing leading edge so that the hotter stream can be discharged directly rearwardly above or below the wing while the cooler stream is lead downwardly or upwardly into the wing structure to the forward ends of the tubular members.

In the case of by-pass or ducted fan gas turbine jet propulsion engines the cooler air stream surrounds the hotter exhaust gas

stream, [illegible] an aircraft using such engines it is advantageous to have twice as many tubular members and having its by-pass air stream split and discharged through both tubular members.

One embodiment of the invention will now be described by way of example.

An aircraft is of generally similar configuration to that shown in Figure 1 of Patent Specification No. 829,753. It comprises a fuselage, a pair of swept-back wings tapered in chord and thickness towards the wing tips, a tailplane provided with elevators, and a fin and rudder. Each wing has a small trailing edge wing flap extending along a major part of its span from its root end as will be explained more fully below. The aircraft landing gear comprises main undercarriage units mounted in the wings and a nose wheel unit mounted in the fuselage. The aircraft is powered by a large number of identical gas turbine jet propulsion engines of the by-pass type distributed along the wing span; thus, in the particular embodiment herein described, there are twelve such engines, six in each wing, but there may of course be a greater or lesser number provided that there is an even number in each wing as will appear below.

The accompanying drawing is a fragmentary perspective view of one wing of the aircraft, the wing being shown as broken off on a chordwise-extending plane and part of wing under surface being shown as broken off on a chordwise-extending plane and part of wing under surface being shown as broken away to reveal the interior construction.

The stress-carrying structure of the wing 1 includes front and rear main spars 2, 3 extending spanwise of the wing. These spars may be of any known construction, but in the present example, the front spar 2 is of box girder construction with upper and lower flanges 2*a* and two vertical webs 2*b* while the rear spar 3 is a simple girder with upper and lower flanges 3*a* and a single web 3*b*. The wing structure further comprises twelve straight cylindrical tubular members 4 of the same constant internal diameter throughout their lengths, extending chordwise of the wing and arranged parallel to one another and side by side along the wing span. Each tubular member 4 extends from a position forward of the front spar 2 through the webs 2*b*, 3*b* of the spars, to which it is rigidly attached, to a position rearward of the rear spar 3. At least some of the tubular members are formed integrally with or have rigidly attached thereto vertical fins 5 extending chordwise between the spars, the edge of the fins conforming to the parts of the wing profile between the spars and each tubular member with its fins together forming one of the ribs of the wing. The upper and lower skins 6, 7 of the wing are attached to the flanges of the spars and to flanges at the edges of the fins 5. These fins may only be required for the more inboard tubular members where their external diameter is less than the wing thickness and they are accordingly entirely buried in the wing as shown in the drawing. At some intermediate position along the wing the tubular member may occupy the whole of the wing thickness while it may be necessary to provide external fairings to enclose the outboard tubular members. Such an arrangement is shown in Figures 8-10 of Patent Specification No. 829,753.

The jet engines generally indicated at 8 are mounted in nacelles 9 extending forwardly from the wing leading edge, each engine having its longitudinal axis substantially in the plane of the axes of the tubular members and lying midway between two adjacent tubular members. The engines are supported from the front spar 2 by a framework (not shown) in known manner.

Each engine is generally as shown in figures 5(a) and 5(b) of Patent Specification No. 829,753. It comprises a low pressure or by-pass compressor, a high pressure compressor, a combustion system and a turbine assembly including a high pressure turbine and low pressure turbine, arranged in that order from front to rear of the engine. The engine is designed to have a high by-pass ratio of the order of 2 or 3 to 1. The by-pass compressor is enclosed by a stator casing 10 while the high pressure compressor, combustion system and turbine assembly are enclosed by a casing 11 of smaller diameter than casing 10. The upstream end of casing 11 constitutes the inlet 12 to the high pressure compressor for part of the air delivered by the by-pass compressor while it defines with the downstream end of casing 10 an annular outlet passage for the remainder of the air delivered by the by-pass compressor which constitutes the by-pass air stream.

The annular outlet passage for the by-pass air from the by-pass compressor is connected to a pair of ducts 13 which have semi-annular inlets 14 which together make up a complete annulus split by a diametral vertical partition 15. These ducts progressively change in a downstream direction to a circular cross-sectional configuration and are connected one to the forward end of each of the two tubular members 4 on each side of the engine whereby part of the by-pass air stream is led into each of the tubular members.

The turbine assembly is connected to discharge into a jet pipe 16 which is cranked so as to lead the hot exhaust gas stream through the under surface of the forward part of the wing forward of the front spar to a rearwardly directed jet nozzle 17 under

the forward part of the [illegible] and relatively close to the heading edg[illegible]o arranged that the hot gases are discharged as a propulsive jet stream below and clear of the wing lower surface. The projecting part of the jet pipe is enclosed by a fairing 18.

Each tubular member 4 has at its rearward end a flange connected to a corresponding flange on the forward end of a jet pipe unit 19 which is shaped to progressively change in cross-section from circular at its forward end to terminate in a long shallow rearwardly directed jet nozzle 20 extending spanwise of the wing for the discharge of a propulsive jet stream. The jet pipes and nozzles are shaped so that the nozzles 20 are contiguous at the edges and together extend continuously along the wing as nearly as possible from root to tip and in any case preferably along a major part of the wing span. The overall spanwise extent of the nozzles is partly determined by structural considerations. Thus, as mentioned above, the inboard tubular members will normally be entirely buried in the wing but it may be necessary to provide fairings on the wing surfaces to accommodate the more outboard tubular members where the wing thickness is reduced. The most outboard tubular member is accordingly located as close as possible to the wing tip while avoiding the necessity for fairings which would give rise to excessive drag, and the position of this tubular member determines how closely the jet nozzles can approach the wing tip. The outboard jet pipes and nozzles may be offset to some extent in an outboard sense relative to the tubular members so as to increase the overall span of the nozzles. In the present embodiment the nozzles together extend along a little more than 80% of the wing span from the root end.

The jet nozzles 20 are arranged to discharge the by-pass air stream supplied to the tubular members as a long thin spanwise extending jet sheet over the upper surface of a small trailing edge wing flap 21 which has a spanwise extent corresponding to that of the jet nozzles and is movable to deflect the jet sheet upwardly and downwardly from the rearward direction. As explained in the above-mentioned prior Patent Specifications, the jet sheet when deflected downwardly interacts with the main stream flow over the aircraft wing in such a way as to modify the aerodynamic pressure distribution and substantially increase the wing lift, the magnitude of which can be varied by varying the setting of the flap. The flap serves to deflect the jet sheet downwardly by what is known as Coanda effect. The flap size depends in part on the depth of the jet nozzle 20 in that the radius of curvature of the forward curved upper surface of the flap 21 must be so related to the nozzle depth as to effect the required deflection. The [illegible]on can be varied to some extent but t[illegible]atio of flap radius of curvature to nozzle depth is not likely to be more than five. Thus in practice the flap chord at any point along the span is quite small, say, 2 to 5% and in any case no more than 10 or at the most 15% of the total wing chord. The nozzle depth decreases along the wing span generally in proportion to the wing chord and so the flap similarly decreases.

The spaces within the wing defined by adjacent tubular members 4 and their fins 5, the front and rear spars 2, 3 and the upper and lower skins 6, 7 of the wing are sealed and constitute integral fuel tanks. Alternatively the spaces may accommodate separately formed fuel tanks. As explained above only the by-pass air streams flow through the tubular members and so the temperature therein is comparatively low. This relatively low temperature makes it possible for the tubular members to serve as stress-carrying members of the wing as well as forming gas flow ducts for the jet streams, and the fire risk is substantially reduced. Moreover, it is not necessary to make the tubular members of special heat resistant materials and the temperature is low enough to allow the tubular members to form parts of the walls of the fuel tanks.

Numerous variations of the above-described embodiment are possible. Thus there may be a different number of engines, and in some cases the whole of the cooler by-pass stream of each engine might be discharged through a single tubular member or it might be split among more than two tubular members. The hot turbine exhaust gas stream might be discharged above rather than below the wing. The engines might be mounted somewhat above or below the leading edge so that the hotter stream is discharged directly rearwardly above or below the wing as the case may be while the cooler stream is led downwardly or upwardly into the main wing structure through ducting connected to the forward ends of the tubular members.

The engines may anternatively be of the ducted fan type. Such an engine comprises a compressor supplying air to a combustion system which in turn supplies combustion gases to drive a turbine assembly connected to drive the compressor, and thrust augmentor blading mounted on the tips of the turbine rotor blading and operating to induce an air flow in a duct surrounding the turbine assembly. Again only the air stream is discharged through the tubular members and the hot exhaust gas stream is discharged separately clear of the wing.

Yet another form of jet engine which might be used is the turbo-rocket. Such an engine has a compressor operating in a main

duct to d[illegible] in air from atmosphere and discharge it as a propulsive jet stream, and a turbine operating in a separate secondary duct, in driving connection with the compressor and driven by rocket gases. Here again the air is discharged through the tubular members in the wing while the hot rocket gases are discharged clear of the wing. In the form of turbo-rocket engine described in British Patent Specification No. 749009 the turbine blades are mounted on the tops of the compressor blades, and in this case the main duct can be connected to discharge directly into the tubular member while the turbine exhaust can be split and led to nozzles below the wing.

WHAT WE CLAIM IS:—

1. An aircraft wing comprising stress-carrying structure including a front spar and a rear spar extending spanwise of the wing and a plurality of straight tubular members arranged side by side along the wing span and extending chordwise of the wing from a position forward of the front spar through the spars to which they are rigidly attached to a position rearward of the rear spar, the tubular members being connected at their rearward ends to rearwardly directed jet nozzles, and further comprising at least one jet engine of the type which in operation produces two propulsive jet streams at different temperatures, the engine being connected to discharge the cooler stream through at least one of the tubular members and jet nozzles and the hotter stream through a separate rearwardly directed jet nozzle outside the wing structure and arranged so that the hottter stream is discharged clear of the wing.

2. An aircraft wing according to claim 1 wherein the upper and lower skins of the wing are rigidly connected to the spars and to the tubular members.

3. An aircraft wing according to claim 2 wherein the tubular members are formed with vertical fins extending chordwise between the spars to the edges of which fins the upper and lower skins are secured.

4. An aircraft wing according to claim 2 or claim 3 wherein fuel is carried in the wing in the space between two adjacent tubular members.

5. An aircraft wing according to claim 2 or claim 3 wherein the space defined by the two spars, the uper and lower skins of the wing, and two adjacent tubular members is sealed and constitutes an integral fuel tank.

6. An aircraft wing according to claim 2 or claim 3 comprising a separately formed fuel tank in the space defined by the two spars, the upper and lower skins of the wing and two adjacent tubular members.

7. An aircraft wing according to any one of the preceding claims wherein each tubular member is of constant circular cross-section throughout i[illegible]gth.

8. An aircraft wing according to any one of the preceding claims wherein the jet engine is of type which in operation discharges a cooler stream surrounding a hotter stream.

9. An aircraft wing according to claim 8 wherein the engine is a gas turbine jet propulsion engine of the by-pass type.

10. An aircraft wing according to claim 8 wherein the engine is a gas trubine jet propulsion engine of the ducted fan type.

11. An aircraft wing according to any one of claims 8, 9 and 10 having a jet engine for each pair of tubular members, the engine being connected to discharge part of the cooler stream through each of the tubular members of the pair.

12. An aircraft wing according to claim 11 wherein the jet engine has an annular outlet for the cooler stream, and comprising a pair of ducts having semi-annular inlets connected to the annular engine outlet and outlets connected to the forward ends of the tubular members.

13. An aircraft wing according to claim 9 and claim 12 wherein the engine comprises a stator casing enclosing the by-pass compressor and a further casing of smaller diameter than the stator casing enclosing the high pressure compressor, combustion system and turbine assembly, the upstream end of the further casing defining with the downstream end of the stator casing the annular outlet for the cooler stream.

14. An aircraft wing according to any one of the preceding claims wherein the engine lies substantially in the plane of the tubular members and is connected to discharge the hotter stream through ducting leading through the wing surface to the separate jet nozzle.

15. An aircraft wing according to any one of claims 1 to 13 wherein the engine is mounted above or below the wing and is connected to discharge the cooler stream through at least one duct leading into the interior of the wing to the forward end of at least one of the tubular members.

16. An aircraft wing according to any one of the preceding claims wherein the jet nozzles at the rearward ends of the tubular members are shaped and directed so that the cooler jet stream is discharged as a long thin jet sheet extending spanwise of the wing, and a jet deflector is provided for deflecting the jet sheet downwardly from the rearward direction.

17. An aircraft wing according to claim 16 wherein the jet sheet extends continuously along the wing span.

18. An aircraft wing according to claim 16 or claim 17 wherein the jet sheet extends along a major part of the wing span.

19. An aircraft wing according to any one

of claims 16, 17 and [illegible]erein the jet deflector is a trailing edg[illegible]wing flap arranged so that the jet sheet is discharged over and follows its upper surface.

20. An aircraft wing substantially as herein described with reference to and as illustrated in the accompanying drawing.

21. An aircraft having [illegible]air of wings, each according to any one of the preceding claims.

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Chartered Patent Agent,
Agent for the Applicant.s.

PROVISIONAL SPECIFICATION

Aircraft

We, POWER JETS (RESEARCH AND DEVELOPMENT) LIMITED, a British Company, of 25, Green Street, London, W.1., do hereby declare this invention to be described in the following statement:—

This invention relates to aircraft operating on the "jet flap" or "jet augmented" flap principle. Examples of such aircraft are described in British Patent Specifications Nos. 787011-5 and in copending applications Nos. 22267/55, 27599/55 and 3749/57, and the principles involved are discussed in a paper by the present inventor published in the Journal of the Aeronautical Society of January 1956.

It has been proposed that a jet flap aircraft should be powered by a number of wing-mounted jet engines arranged to discharge their jet streams so that they leave the wing trailing edge in the form of a long thin jet sheet. This usually necessitates ducting relatively hot jet streams through the wing structure and the fire risk is thereby increased, especially when the fuel tanks are within the wing. The last-mentioned of the above applications disclose an arrangement whereby the fire risk is reduced, and in one aspect the present invention provides an alternative to this earlier proposal.

The present invention is based on the use in a jet flap aircraft of jet engines of the type which in operation produce two propulsive jet streams at different temperatures, and particularly though not exclusively on the use of gas turbine jet propulsion engines of the by-pass and ducted fan types which in operation discharge a relatively cool stream of air in parallel with the high temperature stream of exhaust gases from the turbine. Broadly it is contemplated that only the lower temperature stream shall be used to produce the jet flap effect.

Thus the invention provides an aircraft wing having mounted at its leading edge at least one jet engine of the type which in operation produces two propulsive jet streams at different temperatures, ducting for leading the cooler stream through the wing structure to at least one rearwardly directed jet nozzle arranged to discharge the stream so that it will leave the wing trailing edge as a long thin jet sheet and ducting for leading the hotter stream to at least one separate rearwardly directed jet nozzle outside the wing structure arranged so that the latter stream is discharged clear of the wing.

In this way only the cooler stream has to be led through the wing structure in proximity to the fuel tanks and the fire risk is reduced.

The engines may be mounted in nacelles extending forwardly from the wing leading edge generally in the plane of the wing so that the cooler stream of each engine can be discharged through ducting extending directly rearwardly through the wing while the hotter stream is led through a cranked duct to a nozzle below or above the wing surface and relatively close to the leading edge. In some cases the nacelles might be above or below the wing leading edge so that the hotter stream can be discharged directly rearwardly above or below the wing while the cooler stream is lead through downwardly or upwardly into the wing structure.

The invention is thought to have particular application to aircraft as described in co-pending application No. 3749/57. The stress-carrying structure of the wing of such an aircraft comprises a front spar and a rear spar extending spanwise of the wing and a plurality of straight cylindrical tubes extending chordwise of the wing and arranged side by side along the wing span, each tube extending from a position forward of the front spar through the spars to a position rearward of the rear spars and being rigidly attached to these spars, the rearward end of each tube being connected to a rearwardly directed jet nozzle and a jet engine being mounted at the forward end and connected to discharge a propulsive stream through the tube and jet nozzle. According to the present invention only the cooler stream from the engine is discharged through the tube.

In the case of by-pass or ducted fan gas turbine jet propulsion engines the cooler air stream surrounds the hotter exhaust gas stream, and in an aircraft using such engines it is advantageous to have twice as many tubes as engines, each engine being mounted between a pair of tubes and having its air stream split and discharged through both tubes.

One embodiment of the invention will now be described by way of example. A jet flap aircraft is generally similar to that described in co-pending application No. 3749/57 and

comprises a fuselage, a pair of swept back wings, tapered in chord and thickness, a tail-plane and a fin and rudder, its landing gear comprising main undercarriage units mounted in the wings and a nose wheel unit mounted in the fuselage. The aircraft is powered by a large number of identical gas turbine jet propulsion engines of the by-pass type distributed along the wing span; thus, in the partciular example herein described, there are twelve such engines, six in each wing, but there may of course be a greater or lesser number provided that there is an even number in each wing as will appear below.

The stress-carrying structure of each wing includes front and rear main spars extending spanwise of the wing. These spars may be of any known construction, but in the present example, the front spar is of box girder construction with upper and lower flanges and two vertical webs while the rear spar is a simple girder with upper and lower flanges and a single web. The wing structure further comprises twelve straight cylindrical tubes of constant bore throughout their lengths extending chordwise of the wing and arranged side by side along the wing span, all the tubes being of the same diameter. Each tube extends from a position ahead of the landing edge through the webs of the spars, to which it is rigidly attached, to position aft of the rear spar. At least some of the tubes are formed integrally with or have rigidly attached thereto vertical fins extending chordwise between the spars. The edge of the fins conforming to the parts of the wing profile between the spars and the tube and fins together forming one of the ribs of the wing. The upper and lower skins of the wing are attached to the flanges of the spars and the edges of the fins. The fins may be continued forward of the front spar and run out into the tube to conform to the wing profile.

These fins may only be required for the more inboard tubes where the tube diameter is less than the wing thickness and are accordingly entirely buried in the wing. At some intermediate position along the wing the tubes may occupy the whole of the wing thickness while it may be necessary to provide external fairings to enclose the outboard tubes.

The jet engines are mounted in nacelles extending forwardly from the wing leading edge, each engine having its longitudinal axis substantially in the plane of the axis of the tubes and lying midway between two adjacent tubes. The engines are supported from the front spar by a framework in known manner.

Each engine comprises a low pressure or by-pass compressor, a high pressure compressor, a combustion system, a high pressure turbine and low pressure turbine arranged in that order from front to rear of the engine. The engine is designed to have a high by-pass ratio of the order of 2 or 3 to 1. The by-pass compressor is connected to discharge into an annular duct defined by an outer cylindrical wall forming a continuation of the compressor stator casing and a coaxial inner wall supported from the outer wall by a number of radially extending streamlined struts symmetrically disposed around the axis of the engine. These struts also carry an annular splitter member which divides the annular duct into an outer annular passage for the by-pass air and an inner annular passage leading to the high pressure compressor which comprises a stator casing connected at its upstream end to the splitter member and enclosing a high pressure compressor rotor.

The high pressure compressor is connected to discharge into a combustion system of any known type. The combustion system is in turn connected to discharge into a high pressure turbine having a rotor connected to drive the high pressure compressor rotor through a hollow shaft extending through the combustion system. The high pressure turbine is connected to discharge into a low pressure turbine having a rotor connected to drive the by-pass compressor rotor through a shaft extending coaxially through the high pressure compressor and turbine and the shaft connecting them. The compressor and turbine rotors and the shafts are supported in bearings in known manner.

The outer annular passage for the by-pass air from the by-pass compressor is connected to a duct which is annular at its inlet but split into two 180° sector shaped passages by a diametral vertical partition. These passages progressively change in a downstream direction to a circular cross-sectional configuration and are connected one to the forward end of each of the two tubes on each side of the engine whereby the by-pass air stream is led into the tubes.

The low pressure turbine discharges into an exhaust duct which is cranked so as to lead the hot exhaust gas stream through the underside of the framework and the surface of the nacelle or the forward part of the wing to a rearwardly directed jet nozzle under the forward part of the wing, so arranged that the stream is discharged below and clear of the wing lower surface.

Each tube has at its rearward end a flange connected to a corresponding flange on a jet pipe unit which progressively changes in cross-section from circular at its upstream end to terminate in a long shallow jet nozzle extending spanwise of the wing for the discharge of the jet stream. The jet pipes and

nozzles are shaped so that the nozzles are contiguous at the edges and together extend continuously along the wing as nearly as possible from root to tip and in any case preferably along a major part of the wing span. The overall spanwise extent of the nozzles is partly determined by structural considerations. Thus as mentioned above the inboard tubes will normally be entirely buried in the wing but it may be necessary to provide fairings on the wing surfaces to accommodate the more outboard tubes where the wing thickness is reduced. The most outboard tube is accordingly located as close as possible to the wing tip while avoiding the necessity for fairings which would give rise to excessive drag, and the position of this tube determines how close its jet nozzle can approach the wing tip. The outboard jet pipes and nozzles may be offset to some extent in an outboard sense relative to the tubes so as to increase the overall span of the nozzles. Thus in the present example the nozzles together extend along a little more than 80% of the wing span from the root end.

The jet nozzles are arranged to discharge the by-pass air streams as a long thin spanwise extending jet sheet over the upper surface of a small trailing edge wing flap which is movable to deflect the jet sheet upwardly and downwardly. As explained in the above-mentioned prior specifications and applications, the jet sheet interacts with the main stream flow over the aircraft wing in such a way as to modify the aerodynamic pressure distribution and substantially increase the lift, the magnitude of which can be varied by varying the setting of the flap. The flap serves to deflect the jet sheet downwardly by what is known as Coanda effect. The flap size depends in part on the depth of the jet nozzle in that the radius of curvature of the forward curved upper surface of the flap must be so related to the nozzle depth as to effect the required deflection. The relation can be varied to some extent but the ratio of flap radius of curvature to nozzle depth is not likely to be more than five. Thus in practice the flap chord at any point along the span is quite small, say, 2 to 5% and in any case no more than 10 or at the most 15% of the total wing chord. The nozzle depth decreases along the wing span generally in proportion to the wing chord and so the flap chord similarly decreases.

The spaces within the wing defined by adjacent tubes and their fins, the front and rear spars and the upper and lower skins of the wing are sealed and constitute fuel tanks. Alternatively the spaces may accommodate separately formed fuel tanks. As explained above only the by-pass air streams flow through the tubes and so the temperature therein is comparatively low. This relatively low temperature makes it possible for the tubes to serve as stress-carrying members of the wing as well as forming gas flow ducts for the jet streams, and the fire risk is substantially reduced. Moreover, it is not necessary to make the tubes of special heat resistant materials and the temperature is low enough to allow the tubes to form parts of the walls of the fuel tanks.

Numerous variations of the above-described embodiments are possible. Thus there may be a different number of engines, and in some cases the whole of the cooler stream of each engine might be discharged through a single tube or it might be split among more than two tubes. The engines might be mounted somewhat above or below the leading edge so that the hotter stream is discharged directly rearwardly above or below the wing as the case may be while the cooler stream is led downwardly or upwardly into the main wing structure.

The engines may alternatively be of the ducted fan type. Such an engine comprises a compressor supplying air to a combustion system which in turn supplies combustion gases to drive a turbine assembly connected to drive the compressor, and thrust augmentor blading mounted on the tips of the turbine rotor blading and operating to induce an air stream in a duct surrounding the turbine assembly. Again only the air stream is discharged through the tubes and the hot exhaust gas stream is discharged separately clear of the wing.

Yet another form of jet engine which might be used in the turbo-rocket. Such an engine has a compressor operating in a main duct to draw in air from atmosphere and discharge it as a propulsive jet stream, and a turbine operating in a separate secondary duct, in driving connection with the compressor and driven by rocket gases. Here again the air is discharged through the tubes in the wing while the hot rocket gases are discharged clear of the wing. In the form of turbo-rocket engine described in British Patent Specification No. 749009 the turbine blades are mounted on the tips of the compressor blades, and in this case the main duct can be connected to discharge directly into the tube while the turbine exhaust can be split and led to nozzles below the wing.

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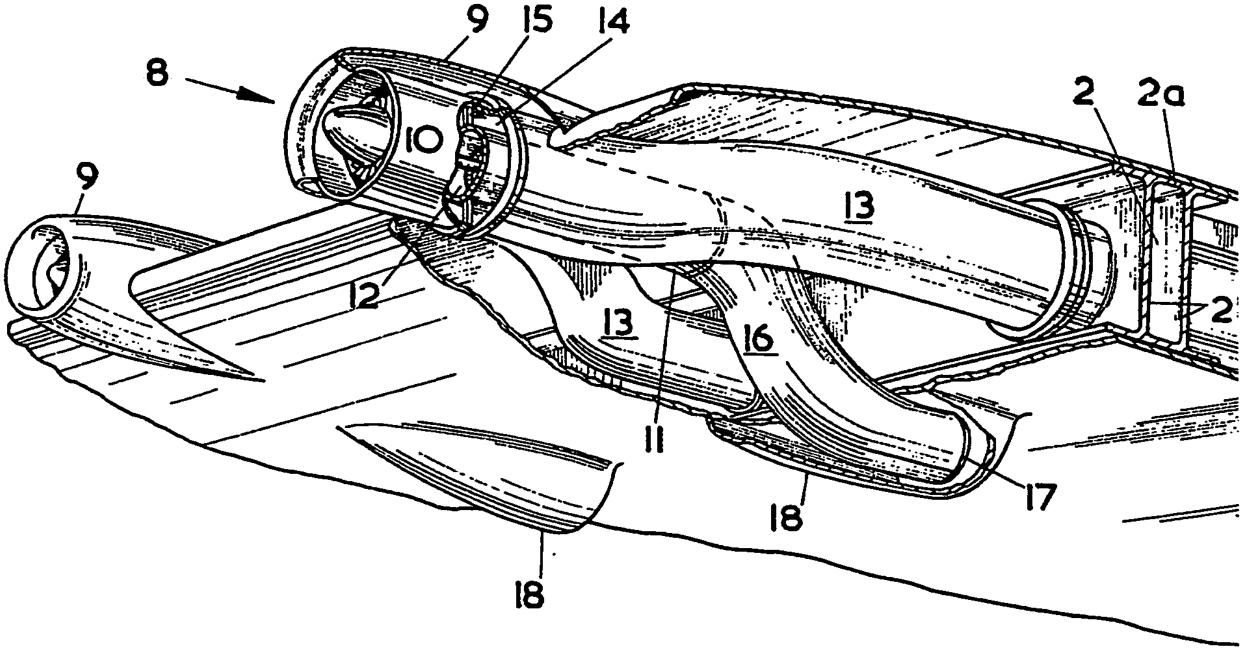
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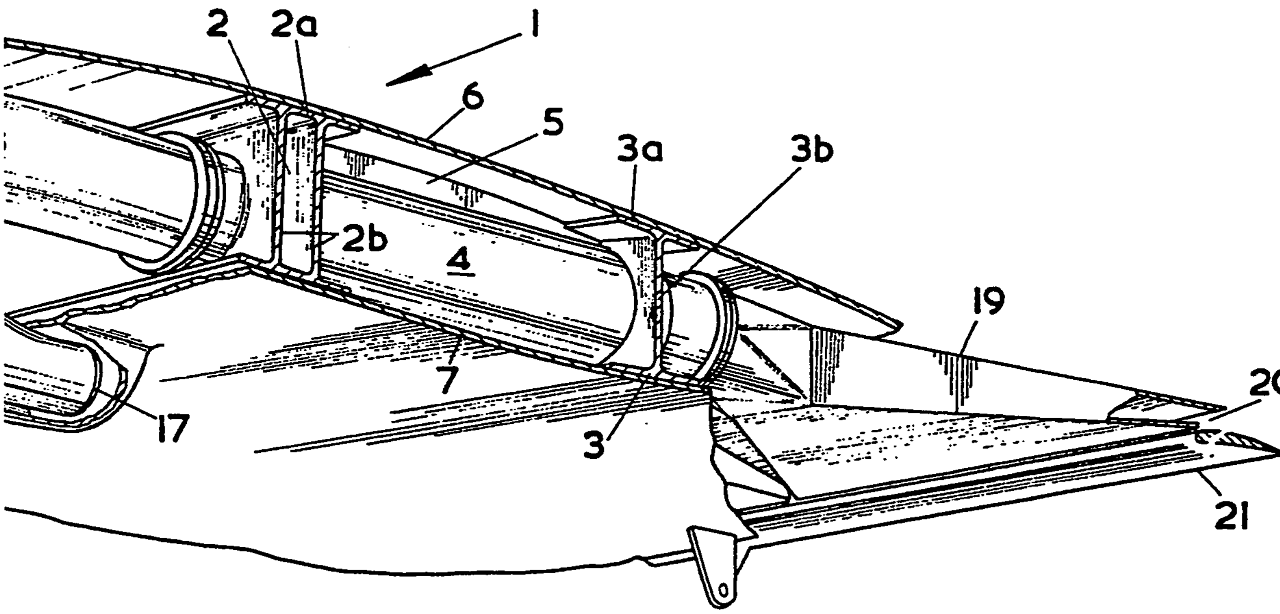

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